VIRTUAL REALITY AND BIM FOR INFRASTRUCTURES

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ABSTRACT:

Building Information Modelling (BIM) has been widely adopted in the construction industry as a means of improving project efficiency, reducing errors, and facilitating collaboration among stakeholders. However, its potential for the infrastructure sector has not been fully explored. Infrastructure projects, such as roads, bridges, tunnels, and airports, are often complex and require the integration of multiple systems and disciplines. BIM has the potential to provide a digital representation of the infrastructure project, allowing for improved design, construction, and maintenance. This paper aims to explore the potential benefits of BIM in the infrastructure sector, examine the challenges to its implementation, and discuss best practices for successful adoption. By analysing a case study and industry trends, this paper will provide insights into how BIM can be leveraged to enhance the efficiency and sustainability of infrastructure projects, ultimately contributing to the development of smarter cities and infrastructure networks. By analysing a case study, this paper will provide insights into how BIM can be leveraged to enhance the efficiency and sustainability of infrastructure projects, ultimately contributing to the development of smarter cities and infrastructure networks. In particular, a virtual modelling in the BIM context of the North-South railway station of Riyadh designed by Arch. Ing. Dia Hilal has been proposed.

1. INTRODUCTION

In 2003, the General Services Administration (GSA), through its Public Buildings Service (PBS) established the National 3D-4D-BIM Program. Since then, this program has evolved into a collaboration between the Public Buildings Information Technology Services (PB-ITS) and PBS, through its Governance Board. The program supports BIM uses across all PBS business lines[1].

The visualization, coordination, simulation, and optimization of 3D, 4D information technologies have boundless potential and BIM allows GSA to more effectively meet customer needs and achieve the objectives of design, construction, resource, facility and program management (Bernal et al., 2022; Schiavinato et al., 2016; Shemyakina et al., 2022). The grossest errors in the BIM project orbit on the 3D model. In fact, not all 3D models qualify as BIM models, the three-dimensional representation of a project is only the initial and central part of the BIM concept, but it is not the project itself (Sacks et al., 2018; Wang, 2012). The model should be considered a support for all the other actors involved in the project due to the interoperability between software and sharing platforms used in the various sectors involved in the design.

Critical to successful integration of computer models into project coordination, simulation, and optimization, as well as asset and facility management, is the inclusion of information—the "I" in BIM. BIM serves as a trusted basis for decision-making and, as a data collection of shared knowledge allows to reduce the need to re-collect or reformat information(Lu et al., 2018).

The challenge of the current GSA is to study the use of BIM technology throughout the life cycle of a building(Arjun R. Pandey & Farzad Shahbodaghlou, 2016; Hou & Remoy, 2021; Shemyakina et al., 2022).
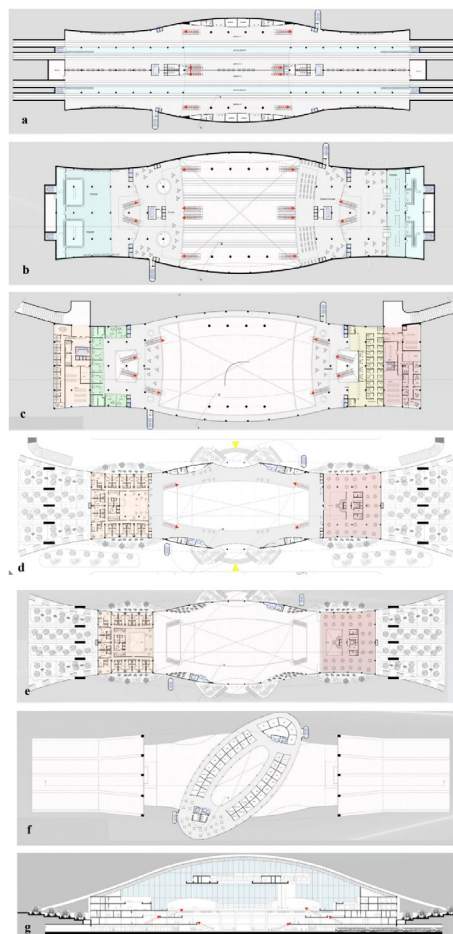
Figure 1. Plans and section of the Riyadh railway station project (Arch. Eng. Diaa Hilal): a) basement 3; b) basement 2; c) basement 1; d) ground floor; e) first floor; f) mall plans; g) cross section.

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BIM can be also considered as a collection of technology-reliant processes which depend heavily on a well-planned and coordinated infrastructure. The tools used to develop the information model need to provide the user with the ability to associate the required data to the assets in the model. The tools used to house these models as they are developing must allow stakeholders continuous access to data. This process therefore requires a collaborative environment that allows data to flow throughout the lifecycle of the project. With BIM data available, construction analysis can start sooner, which in turn provides better engineered solutions.

The model of the north-south Riyadh railway station designed by Arch. Ing. Diaa Hilal has been created starting from the project drawings (Figure 1) to optimize the 3D modelling aimed at the BIM approach.

The benefits of BIM increase as more stakeholders can access and consume the wealth of information it contains. BIM competency levels will vary by role, each with a balance of strategic education and technical training (Arjun R. Pandey & Farzad Shahbodaghlou, 2016; Sanchez et al., 2014; Vacanas et al., 2016). Education across the organization or project team allows for consistent messaging and clearer understanding of the change in mindset and strategy required(Eynon, 2016; Kelly et al., 2013). Training focuses on role-specific needs that should be timed appropriately. As a general rule, education sessions should be held in person with a diverse set of roles. Conversely, technical training can be recorded internally or curated externally from online resources (Figure 2, Figure 3).

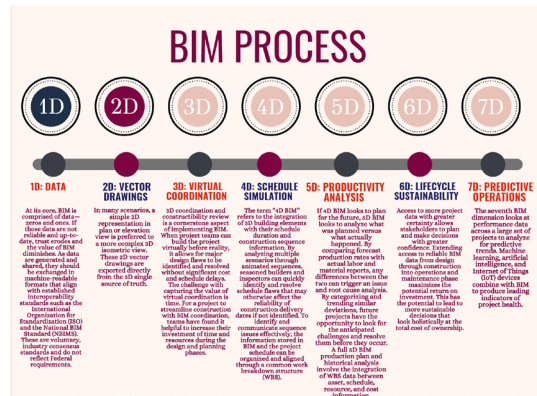In the complex process of BIM project, the 1D, 2D, 3D models have been developed. (Fig. 4)

Figure 2. Managers need process.

Figure 3. Matrix progression.

Figure 4. BIM Process.

The level of detail (LOD) is the general state of the information model at a particular point in the design process and includes not only the graphical objects, but also the data associated with the objects (Sacks et al., 2018). The five different levels of detail represent the progression of the model. The model does not progress equally for all elements. For example, structural analysis on some parts may be at the 400 level, while mechanical fittings still at 200. Specific disciplines will also progress through the process at different rates. It is very common for structural steel to reach level 400 before all mechanicals have reached level 300. The entire team must recognize this and plan accordingly, making sure items do not make it into the field if their final design will be impacted by objects not yet defined in the model. For example, steel should not be released from level 300 before the mechanical loads are known. The level of detail (LOD) is the general state of the information model at a particular point in the design process and includes not only the graphical objects, but also the data associated with the objects (Sacks et al., 2018). The five different levels of detail represent the progression of the model. The model does not progress equally for all elements. For example, structural analysis on some parts may be at the 400 level, while mechanical fittings still at 200. Specific disciplines will also progress through the process at different rates. It is very common for structural steel to reach level 400 before all mechanicals have reached level 300. The entire team should be able to recognize this, making sure items do not make it into the field if their final design will be impacted by objects not yet defined in the model. For example, steel should not be released from level 300 before the mechanical loads are known. This is not to say that the mechanics must be as complete as they are, just that the loads needed to calculate the steel are correct (Gu et al., 2020; Soh et al., 2022).

2. METHODOLOGY AND CASE STUDY

The first part concerns the study of the architectural project of the station in all its parts. The preliminary design consists of several elements, including entrance, waiting areas, baggage area, railway station, general administration, contact and remote-control centres, ticket offices, refreshment areas, shops, offices, public services, etc.

The infrastructure concept starts from the location of the railway station itself, i.e., the city of Riyadh. This means that it is a development project within a desert city, also referred to as the city of sand dunes. The project idea is to reproduce a sand dune, built with a modern structural system.

After importing .jpeg files to Revit, the first step for the 3D modelling of the building has been the creation of the structural
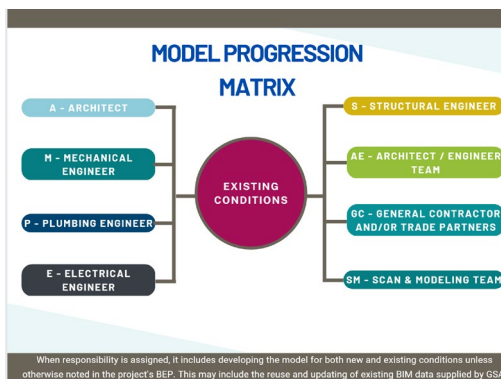
model of the station, by following the plan and section shapes of the original design.

The modelling of the structure has been performed by means of levels (Figure 5), created starting from the longitudinal section information (Figure 1g). Furthermore, following the information present in the plan drawings (Figures 1 a-f) it has been possible to draw grid lines as a guide for the 3D model construction (Figure 6). The structural part of the building in elevation, created by setting the structural discipline for the various elements, consists of reinforced concrete pillars with different diameters, of walls in reinforced concrete, of basement and of lift shafts and stairwells (Figure 7).
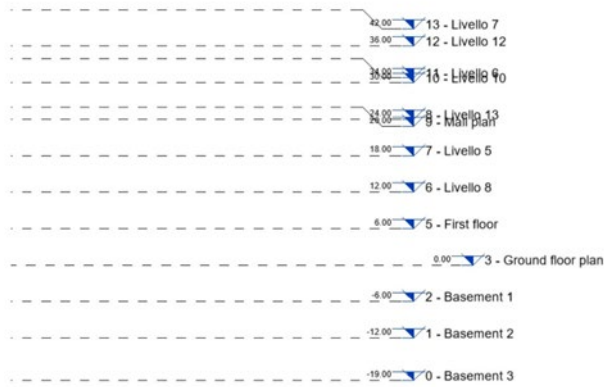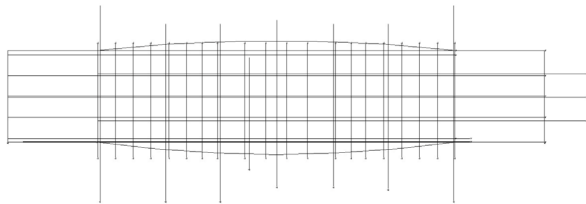

Figure 5. Revit levels.

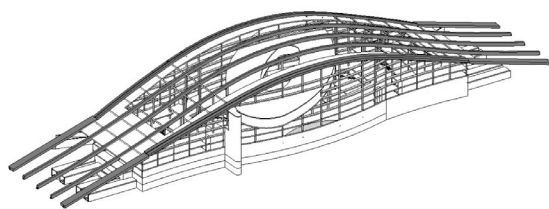**Figure 6**. Grid creation within Revit.

Figure 7. 3D view of the structural model.

For the creation of the structural part of the roof, to resort to organic modelling has been necessary, starting from the creation of the roof structure mass of the building (command: massing and building site local mass). The same mass has been subsequently divided by means of a grid system, to create the anchor points necessary for the adaptation of the beam system to the desired shape (Figure 8).
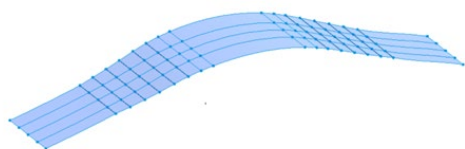

Figure 8. Mass for creating the structural part of the roof.

Several adaptive elements have been created ("generic adaptive metric model" family) to model the roof structure, which could precisely adapt to the previously created mass. In particular, families of 2-to-9-point adaptive parametric beams, a 7 point adaptive parametric beam with rotation and a family of 3 point circular adaptive beams with variable radii have been created (Figure 9).
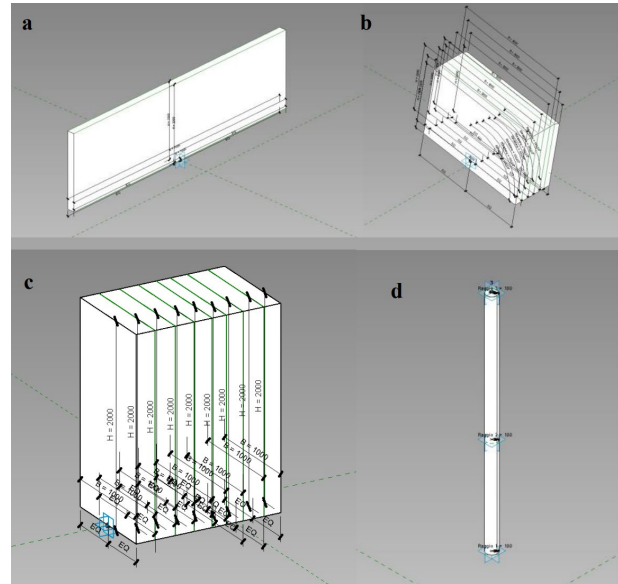

Figure 9. Adaptive families of beams a) 2 points, b) 7 points with rotation, c) 9 points, d) circular 3 points.

For the modelling of the roof structure, an additional mass has been also created to build the part of the roof envelope, created with the basic roof family (Figure 10).
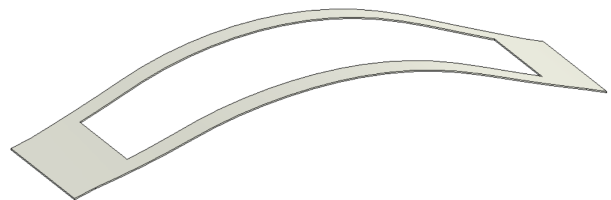

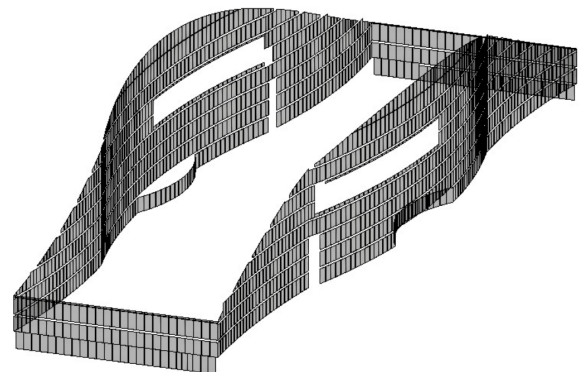**Figure 10**. Basic roof, generated from the mass.

Figure 11. Curtain wall panels with vertical division, used to create the external envelope.

After the creation of the structural part, the architectural aspect of the 3D model has been completed with the creation of the external envelope. The side parts of the envelope are made with

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curtain wall panels with vertical division (Figure 11), however, a further mass divided into grids with glazed adaptive panels has been generated (Figure 12). The adaptive glazing panel are created starting from the "pattern-based metric curtain wall" family, also creating the parametric frame of the same panel (Figure 13).
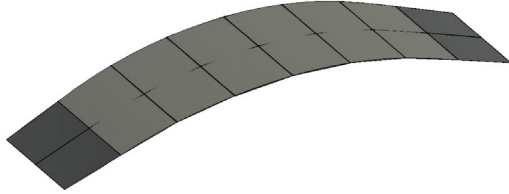

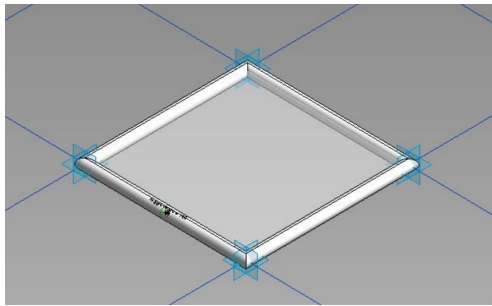**Figure 12**. Mass for the glazed part of the roof creation.

Figure 13. Adaptive parametric panel generated for the glazed part of the roof creation.

After the structural part and the external envelope creation, the 3D model of the station has been completed with the internal divisions (Figure 14), with the insertion of vertical connections (stairs and lifts) and with the insertion of railings and doors in each floor (Figure 15), by assigning the respective materials to each component element of the model from the Revit material browser. With respect to the original project, changes have been made as regards the distribution of the rooms, trying however to keep the forms and functions unchanged.
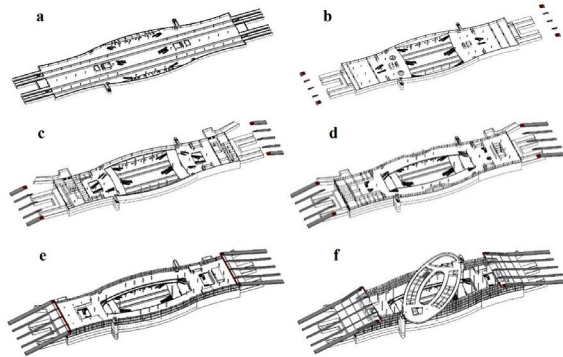

Figure 14. Sections of the 3D model created with Revit (complete with external casing, internal divisions, fixed furnishings, railings and doors): a) basement 3; b) basement 2; c) basement 1; d) ground floor; e) first floor; f) mall plans.
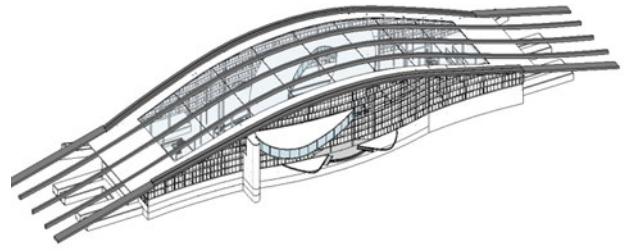
Figure 15. View of the complete 3D model, created with Revit 2021 software.

Using the Revit software, with reference only to the floor indicated as "mall plan", the plan with the identification of the rooms (Figures 16-17), and the rooms abacus, with information relating to surfaces and volumes (Figure 18) have been generated.

Figure 16. Plan generated with the identification of the rooms.

Figure 17. Table referred to plan in Figure 15.

Figure 18. Table referred to plan in Figure 15.

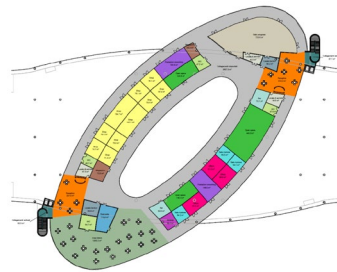The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-2/W3-2023
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3. RESULTS

A customized A0 format title block has been created for the final layout of some of the project's technical documents (Figure 22). In addition to the floor plan of the "mall plan", a detailed view of the lift block with personalized labels (Figure 19), elevations (Figure 20) and sections (Figure 21) have also been inserted in the table.
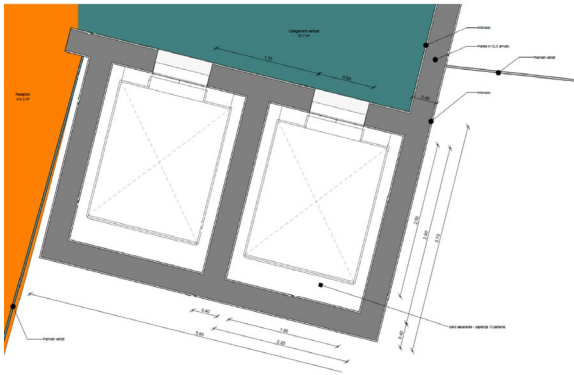
Figure 19. Table referred to plan in Figure 15.
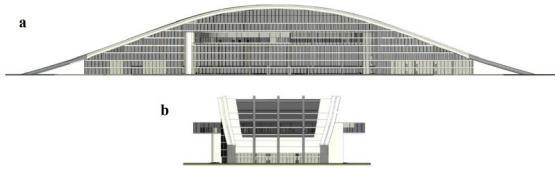
Figure 20. Elevation detailed view.
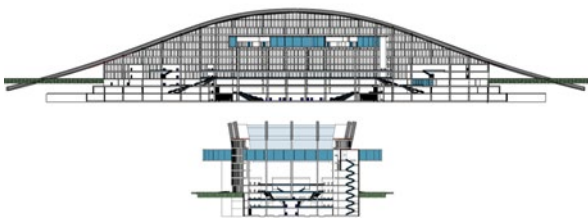
Figure 21. Cross sections detailed view.
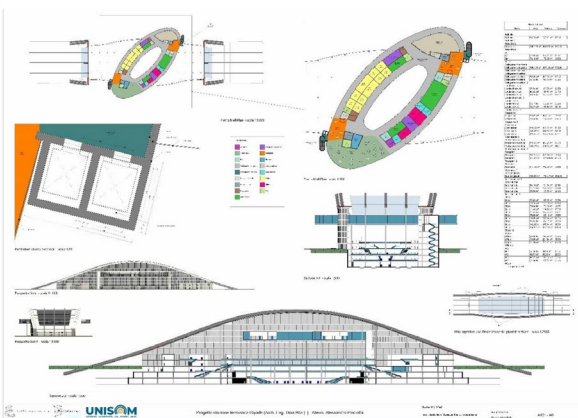
Figure 22. Customized A0 format title block created for the final layout of some of the project's technical documents.

A second table in A1 format (Figure 23) for inserting the 3D view of the model (Figure 23-15), the cutaways (Figure 23-14) and a structural exploded view have been produced. Concerning the cross-sections of the 3D model, a post-processing has been carried out with Photoshop for the insertion of indications on the several use destinations of the spaces of the station, by inserting coloured fills, lines and texts.
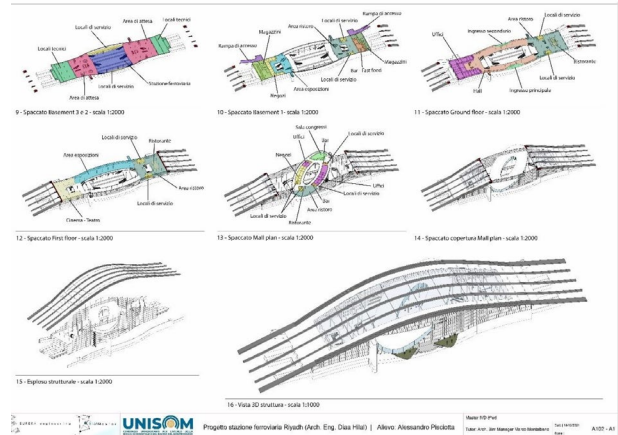
Figure 23. Customized A1 format with 3D view, cataways and exploded view of the model.

For the realization of the internal renderings, the Enscape v.3.3 software has been used. Enscape is a rendering software that is installed directly on Revit. Through this software it is possible to generate renderings directly from the Revit model, since the materials set in the Revit elements are directly recognized. Additionally, further materials can be loaded into Revit elements via the Enscape material library (Figure 24). In this case, all materials have been set from the Revit library except for only a few floors which have been set from Enscape material library.
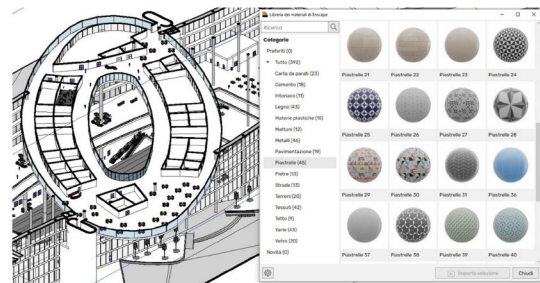
Figure 24. Enscape v.3.3 material library.
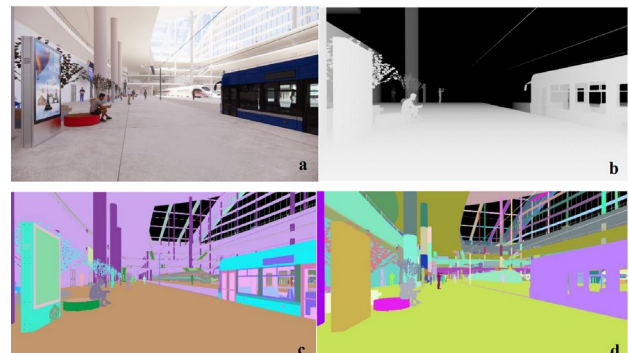
Figure 25. Rendering carried out by Enscape: a) render; b) depth; c) materialID; d) objectID.

The renderings processed in Enscape have been post-processed in Photoshop, where the masks returned by Enscape are fundamental for the selection operations. Various commands and

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effects available on Photoshop have been used in the post-processing for each render, including: the sharpness filter unsharp mask, suitably setting the filter parameters; tonal value adjustments have been applied, also with the help of ID selection masks; colour corrections have been made with RGB curves adjustments. For some renders, further image improvements and/or corrections of small errors have been made, with some of the tools present in Photoshop, such as clone stamp, saturation adjustment, etc.

For all renders the masks have been obtained, as shown in the precious example (Figure 25). For comparison, only the pre- and post-processing renderings of the internal environments of the train station obtained with Enscape and enhanced with Photoshop are shown below (Figures 26 to 35).

Figure 26. Indoor rendering processed in Enscape software (Basement 3), without post-production.

Figure 27. Indoor rendering processed in Enscape software (Basement 3), with post-production in Photoshop.

Figure 28. Indoor rendering processed in Enscape software (Basement 3), with post-production in Photoshop.

Figure 29. Indoor rendering processed in Enscape software (Basement 2), with post-production in Photoshop.

Figure 30. Indoor rendering processed in Enscape software (Basement 3), with post-production in Photoshop.
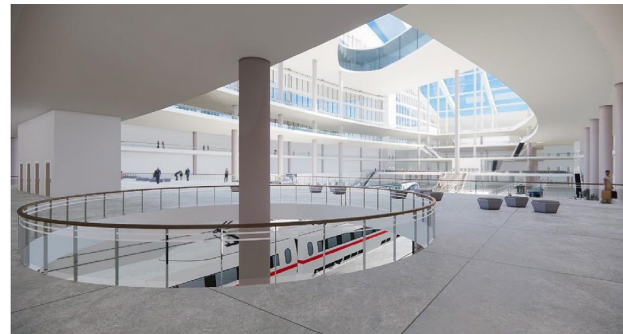
Figure 31. Indoor rendering processed in Enscape software (Basement 2), with post-production in Photoshop.

Figure 32. Indoor rendering processed in Enscape software (Basement 1), with post-production in Photoshop

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Figure 33. Indoor rendering processed in Enscape software (First Floor), with post-production in Photoshop.

Figure 34. Indoor rendering processed in Enscape software (Basement 3), with post-production in Photoshop.

Figure 35. Indoor rendering processed in Enscape software (Mall Plan), with post-production in Photoshop.

Lumion 12.5 software to process the external renderings has been used. Before exporting the model to Lumion, to build a base of the area outside the station in Revit, using the "volume and construction site → topographic surface" command has been considered appropriate. The several 3D elements of the external area have also been built in Revit, such as ramps and low walls since there is no possibility of modelling elements in Lumion (Figure 36). After creating a base for the external area, the 3D model generated in Revit has been exported in *.fbx format, for subsequent uploading to the Lumion software.
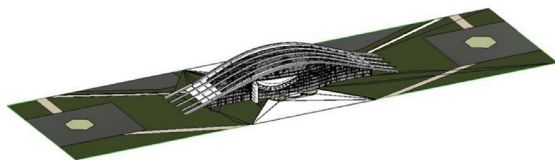
Figure 36. Topographic surface in Revit.

In the uploaded model in Lumion, all materials have been assigned to external elements and additional elements such as street furniture, vegetation, people, and cars have been loaded in different layers, divided by category, to have a better management of the same (Figure 37).
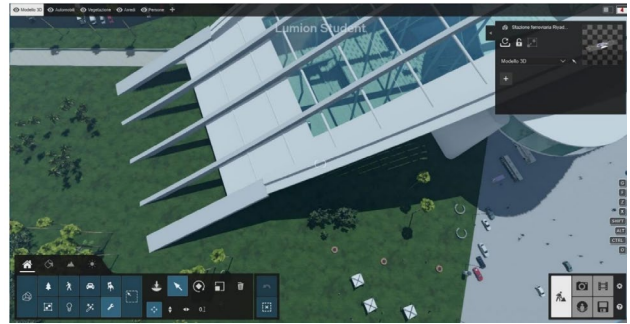
Figure 37. Workflow screenshot in Lumion software: assignment of materials and loading of elements.

After the assignment of the materials and the loading of the 3D elements of outdoor furniture, the "open street map" command of Lumion has been employed to set the surrounding landscape by geolocating the entire 3D model. By defining the position, through the choice of longitude and latitude, the software has been returned a 3D map made up of the overall dimensions of the buildings actually existing in the surrounding area (Figure 38).

Figure 38. Lumion screenshot for loading 3D maps from "open street map"

Below an external render made with the Lumion 12.5 software is shown (Figure 39). Given the high quality of the returned renders, no post-production has been performed for it.

Figure 39. Lateral exterior render (West side), in Lumion 12.5 software.

In Figure 40 the conclusion of the project in all its aspects is shown.

Figure 40. Table 3 (A0 format): indoor and outdoor renderings.

4. CONCLUSIONS

The case study examining the use of Building Information Modelling (BIM) in Revit for station design demonstrates the potential benefits of adopting this technology in the infrastructure sector. The use of BIM in Revit allowed for improved project efficiency, reduced errors, and facilitated the coordination of multiple disciplines involved in the station design. The successful implementation of BIM in Revit in this case study highlights the importance of utilising software with advanced features that allow for easy integration of BIM. It is crucial to adopt standardized data management and effective collaboration protocols to ensure the smooth implementation of BIM in infrastructure projects. Overall, the use of BIM in Revit has the potential to enhance the design, construction, and maintenance of infrastructure projects, ultimately contributing to the development of smarter and more sustainable cities and infrastructure networks.

In this case study, the maximum level of detail has been reached, considering that this LOD has been followed its own progression path independently of the studies related to the other elements of BIM. The future goal is to create a BIM model that starts from this 3D model to arrive at 7D.

5. AKNOWLEDGEMENT

REFERENCES

Arjun R. Pandey, & Farzad Shahbodaghlou. (2016). Measuring Contribution of BIM (Building Information Modeling) to the Construction Sustainability Goals. *Journal of Civil Engineering and Architecture*, *10*(3). https://doi.org/10.17265/1934-7359/2016.03.013

Bernal, I. F. M., Lozano-Ramírez, N. E., Cortés, J. M. P., Valdivia, S., Muñoz, R., Aragón, J., García, R., & Hernández, G. (2022). An Immersive Virtual Reality Training Game for Power Substations Evaluated in Terms of Usability and Engagement. *Applied Sciences (Switzerland)*, *12*(2). https://doi.org/10.3390/app12020711

Eynon, J. (2016). Construction Manager's BIM Handbook. In *Construction Manager's BIM Handbook*. https://doi.org/10.1002/9781119163404

Gu, P., Tao, F., & Wang, G. (2020). Application of BIM technology in fine design in steel structure bridges. *IOP Conference Series: Earth and Environmental Science*, *474*(7). https://doi.org/10.1088/1755-1315/474/7/072016

Hou, C., & Remoy, H. (2021). *Digital Twins to Enable Smart Heritage Facilities Management: A Systematic Literature Review*. https://doi.org/10.15396/eres2021_21

Kelly, G., Serginson, M., Lockley, S., Dawood, N., & Kassem, M. (2013). BIM for facility management: a review and a case study investigating the value and challenges. *Proceedings of the 13th International Conference on Construction Applications of Virtual Reality*.

Lu, W., Lai, C. C., & Tse, T. (2018). BIM and Big Data for Construction Cost Management. In *BIM and Big Data for Construction Cost Management*. https://doi.org/10.1201/9781351172325

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM Handbook. In *BIM Handbook*. https://doi.org/10.1002/9781119287568

Schiavinato, L., Colombelli, S., Eccher, G., Nave, D., Cucino, P., & Bona, N. (2016). BIM use in the Infrastructural field: The case of the extension of the railway in the underground track of Catania, from the Central station F.S. to the airport. *ITA-AITES World Tunnel Congress 2016, WTC 2016*, *3*.

Shemyakina, T. Yu., Gorelova, O. A., & Dyudyun, T. Yu. (2022). *Smart Technologies for Managing the Urban Environment: The Use of "Digital Twins."* https://doi.org/10.1007/978-3-030-94870-2_11

Soh, M. F., Bigras, D., Barbeau, D., Doré, S., & Forgues, D. (2022). Bim machine learning and design rules to improve the assembly time in steel construction projects. *Sustainability (Switzerland)*, *14*(1). https://doi.org/10.3390/su14010288

Wang, X. (2012). BIM Handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors. *Construction Economics and Building*, *12*(3). https://doi.org/10.5130/ajceb.v12i3.2749